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SUMMARY MODELS OF CROP PRODUCTION TO ADDRESS QUESTIONS ON RESOURCE-USE INTERACTIONS AND EFFICIENCIES AT FARM–SCALE

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Introduction
In smallholder systems of sub-Saharan Africa (SSA) resources for crop production such as land, water, nutrients and labour are often available at sub-optimal levels, and their multiple interactions determine resource use efficiencies, crop productivity and system sustainability. Decisions on resource allocation are often made at farm rather than at plot scale. Use of generic summary models of crop production rather than complex mechanistic, process-based models shows promise in addressing cross-scale questions. Changing the spatio-temporal resolution of a model may lead to new processes becoming important, such as the spatial soil heterogeneity characteristic of these systems. Though simpler models generally have less explanatory power, they often perform as well as, or better than complex models, while the uncertainty caused by both lack of data and imperfect knowledge on some processes is better managed. We propose the use of a dynamic summary model able to capture essential processes and resource interactions that determine crop productivity in the short- and the long-term, while keeping a level of simplicity that allows its parameterisation, use and dissemination in the tropics.

Methodology
The crop/soil model FIELD (**F**ield-scale resource **I**nteractions, use **E**fficiencies and **L**ong term soil fertility **D**evelopment, www.africanuances.nl) has been calibrated and tested against long term experimental data for major crops grown in smallholder systems of SSA to simulate resource interaction and their effect on resource capture and conversion efficiencies. The approach combines the use of field data, expert knowledge and, whenever possible in terms of data availability, detailed process-based models to generate functional relationships in the form of response curves or surfaces that can be built within the farm-scale summary model, reducing model calibration-parameterisation efforts. Detailed models can be calibrated against experimental data from locations were intensive research has been conducted, developing functions for an ample range of agroecological conditions to allow interpolation. This is the case when using the model DYNBAL (Tittonell et al., 2006) that has been calibrated and tested for Kenya, to simulate potential and water-limited crop growth for a certain location. Here, we illustrate applications of the summary model FIELD in Kenya, while methodological details can be found in Tittonell et al., 2007.

Results
An example of a summary functions generated using DYNBAL is the relationship between planting date and the fraction of seasonal radiation intercepted by a maize crop (FRINT – Fig. 1 A). Functions to correct FRINT by planting date, plant density, crop/cultivar type are built into FIELD, which can then be used to simulate long-term scenarios of crop or soil management. Long-term experiments involving crop and soil management options are scarce in SSA. Fig. 1 B and C illustrate simulated and measured yield variability and changes in soil organic C for a sandy-loam soil in Central Kenya, with 13 years (or 26 seasons: the long and the short rains) of data for maize cultivated with and without annual applications of animal manure. Once the model is parameterised and tested for a certain location/crop, it is used in farm-scale analyses coupled with livestock and household subsystem models. Despite the use of summary functions in FIELD,, the sensitivity of the model for explorations within the crop/soil subsystem is still satisfactory. Fig. 1 D-G illustrate a case from western Kenya: the model tested to simulate production of sweet potato was applied to predict yields in six fields where farmers normally grow this crop (often the poorest fields) (Fig. 1 D) and nutrient management options involving use of organic and mineral fertilisers were explored. In most treatment*field combinations farmers' yields were improved, but crop responses were

dictated mostly by resource (nutrient, water) interactions, while single nutrient availabilities (soil + fertiliser) explained little of the yield variation.

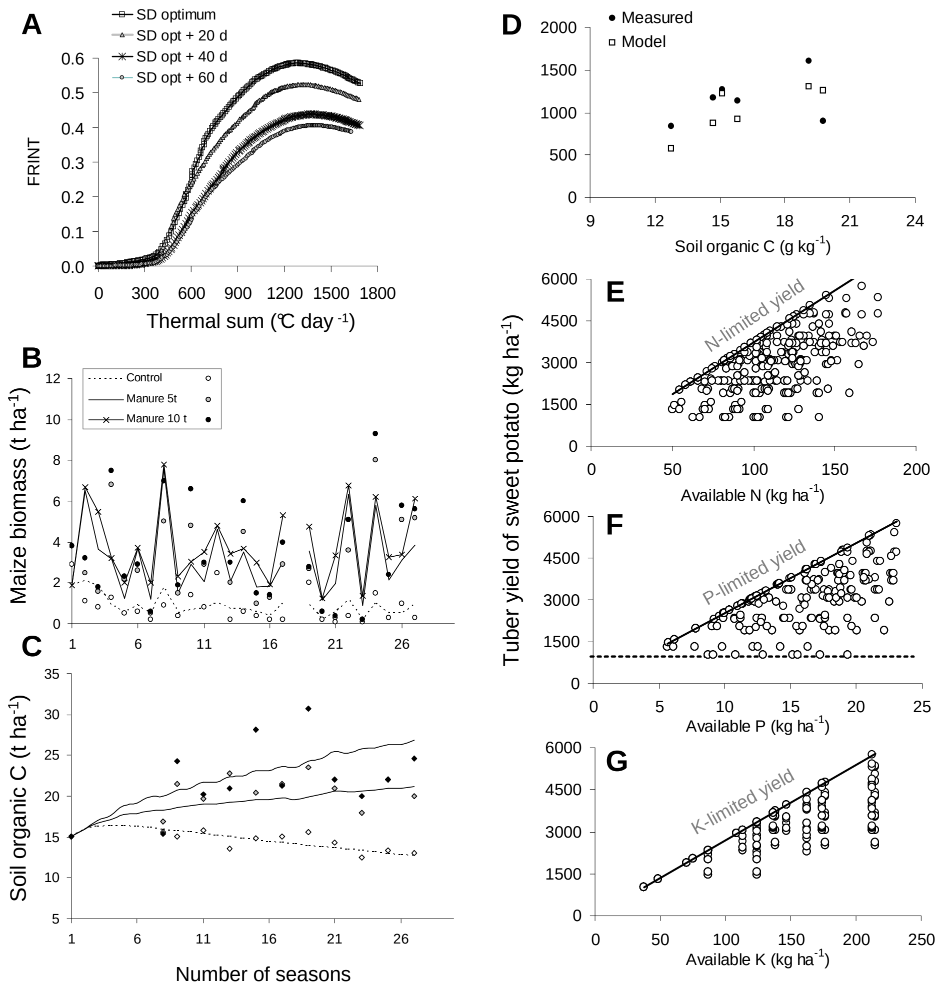

Figure 1: Simulations with the model FIELD – see text for explanation

Conclusions

In data-scarce environments such as SSA, uncertainty in parameter values constraints the performance of detailed process-based models to analyse management options for smallholders. For example, to find out about crop residue management from farmers normally the 'five-fingers method' is used: out of these five fingers, how many fingers represent the fraction of residues incorporated to the soil, fed to livestock or used as fuel? Models often have to be parameterised with data collected in this way, subject to ample intrinsic error (i.e. at least 20% in this case). Under such circumstances, little gain in accuracy can be expected from increasing the degree of detail of the processes modelled. Likewise, models requiring a large number of parameters force model users in SSA to make use of a large number of 'guesstimates' for parameters that are seldom measured in practice. In analysing questions on system design and resource allocation at farm scale in SSA, simple yet dynamic models of the various subsystems (crop, soil, livestock, manure) may suffice. Such models can also be seen as 'process-based', but using a level of detail (and a temporal step) relevant to the scale of the questions raised.

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